RHIC Detector Workshop:

R&D for Future Detectors and Upgrades

BNL, November 13-14, 2001

Convenor's Report: Working Group on Gas Tracking Detectors

Itzhak Tserruya

Outline

- **Introduction**

  *** General guidelines**

  *** Two detectors under consideration**

- **An HBD for low-mass e^+e^- pairs measurement**

- **A compact, fast, multipurpose TPC**

- **R&D program**

General Guidelines

For each proposed new detector, this working group tried to answer the following questions:

- What is the **physics motivation** for the new detector ?
- What are the **system specifications** to perform this physics?
- What is/are the **technological choices**?
- Is there need for an **R&D** phase? If yes:
  - what are the goals of the R&D?
  - provide an estimate of the **time/cost of R&D** phase
- Give an estimate of **time/cost for detector implementation**
- Does the new detector have any **impact on the collider**? For example does it require high luminosity? Or can the new detector cope with an increase of RHIC luminosity by one order of magnitude?
- How does the proposed detector **fit into existing experiment** ? What is the additional data volume? Does it impact on the DAQ?

Hadron Blind Detector (HBD) for PHENIX *

- **Physics Motivation:**
  - *** thermal radiation, CSR**
  - *** update**

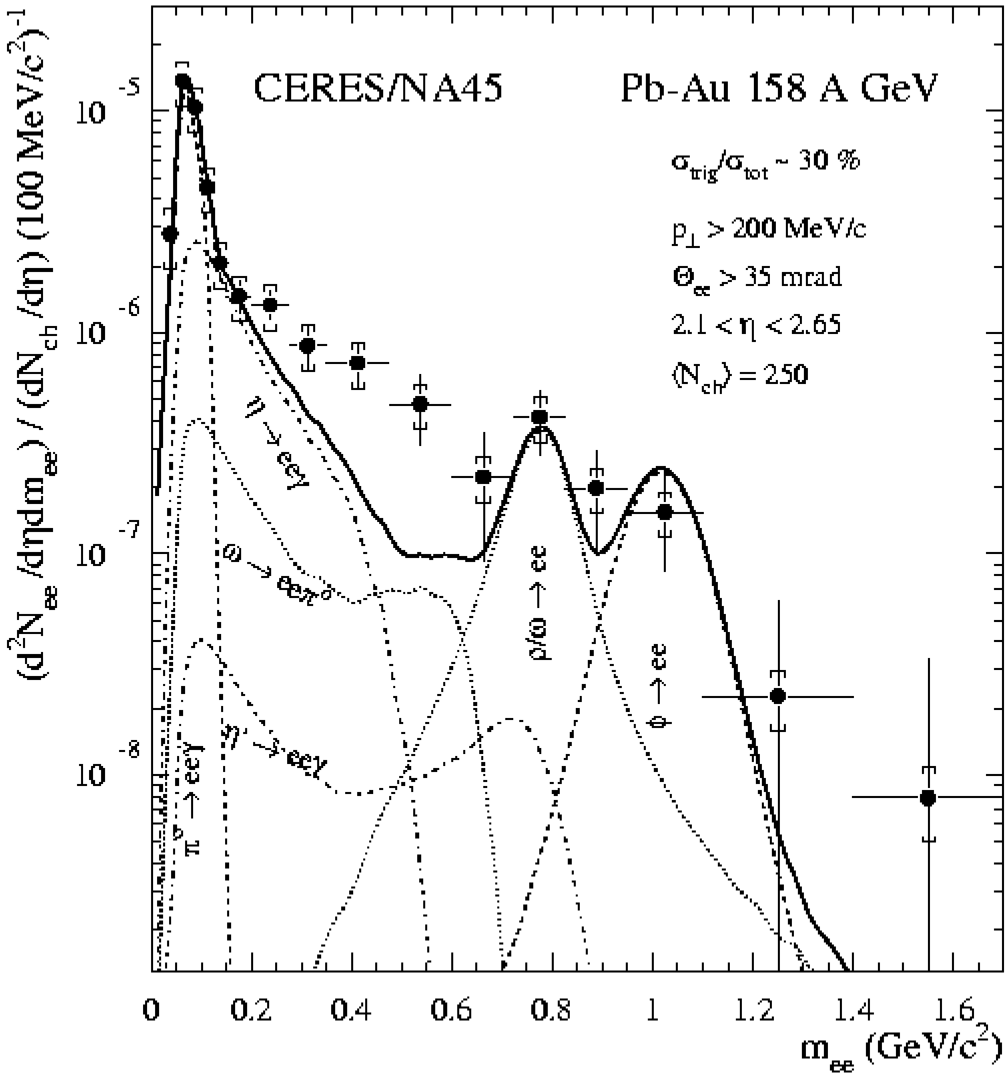
- **Principle simulations ⇒ System specifications ⇒ Concept ⇒ ⇒ R&D Program**

*** see: PHENIX Technical Note 391:**

"Proposal for a Hadron Blind detector for PHENIX"

http://www.phenix.bnl.gov/phenix/WWW/forms/info/view.html

Low-mass Dileptons: Main CERN Result

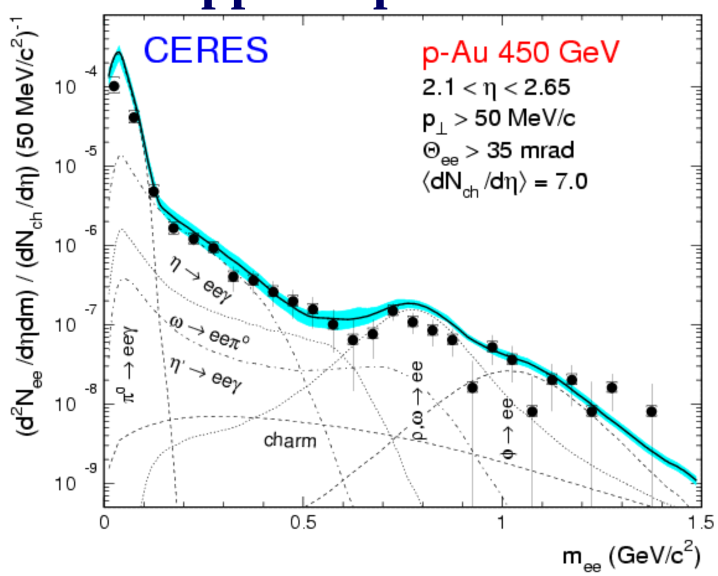


Strong enhancement of low-mass e^+e^- pairs in A-A collisions

(wrt to expected yield from known sources)

Enhancement factor (.25 <m<.7GeV/c^2) :
2.6 ± 0.5 (stat) ± 0.6 (syst)

No enhancement in pp and pA collisions

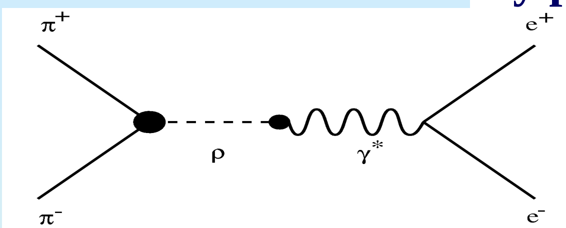


Interpretations

Add

$\pi\pi$ annihilation: $\pi^+\pi^- \rightleftarrows \gamma^* \rightleftarrows e^+e^-$ (thermal radiation from HG)

Cross section dominated by pole at the ρ mass of the π em form factor:

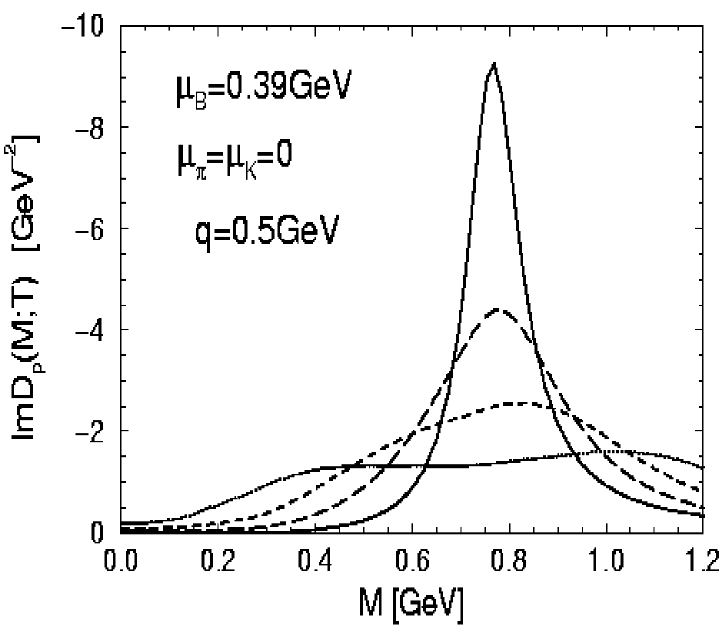


$$F_\pi^2(m) = \frac{m_\rho^4}{(m_\rho^2 - m^2) + m_\rho^2\,\Gamma_\rho^2}$$

Plus

ρ-meson broadening

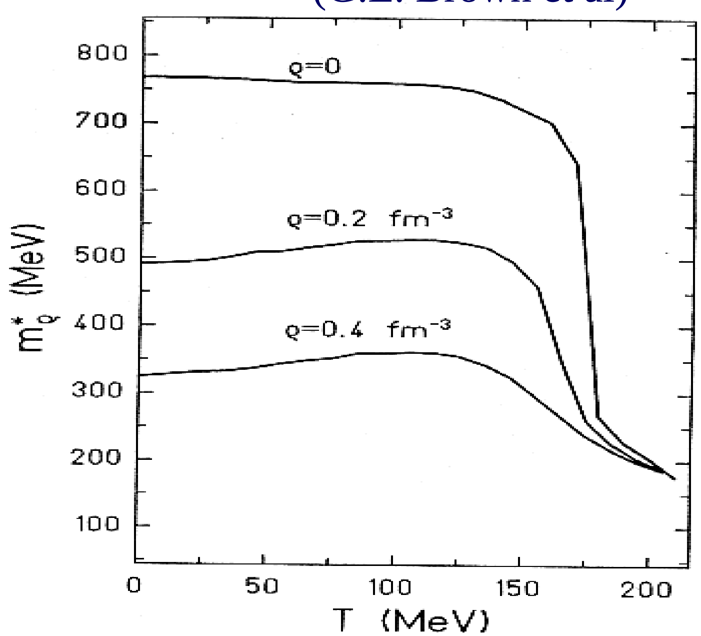
ρ scattering off baryons(Rapp, Wambach et al)



or

Dropping ρ-meson mass

(G.E. Brown et al)



Onset of Chiral Symmetry Restoration?

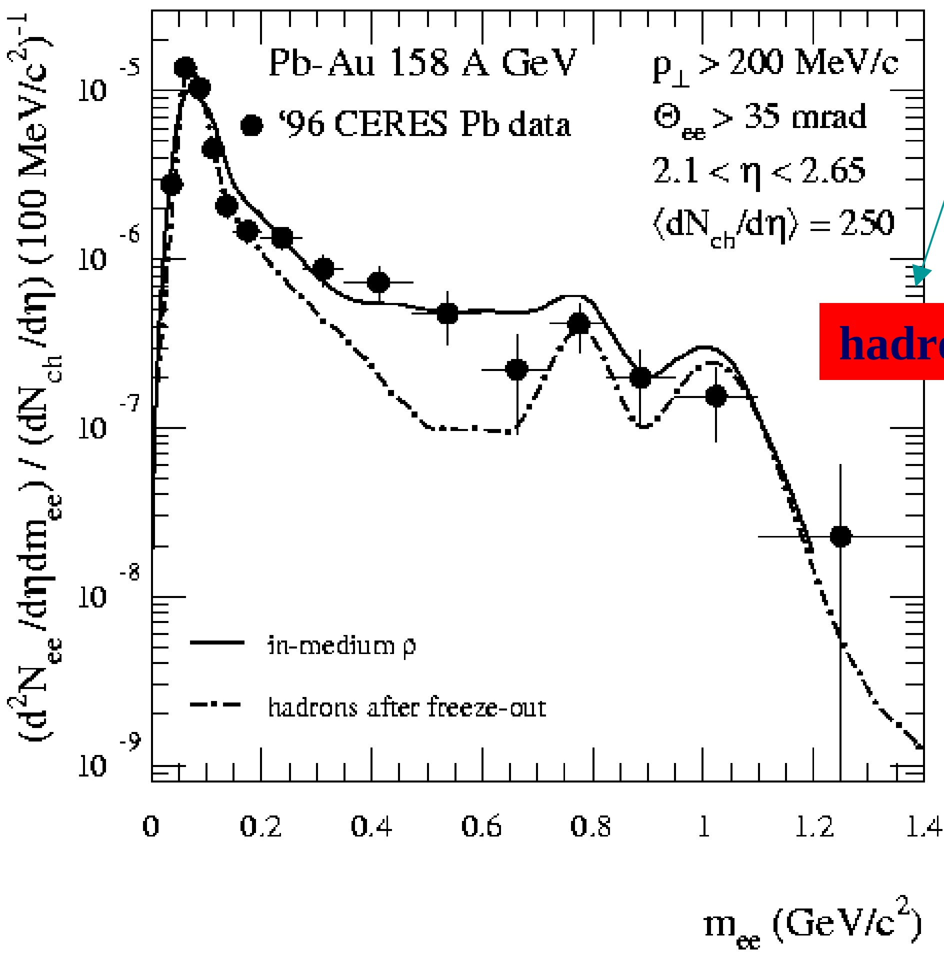
In-medium ρ-meson broadening

(Rapp, Wambach et al)

d.o.f.

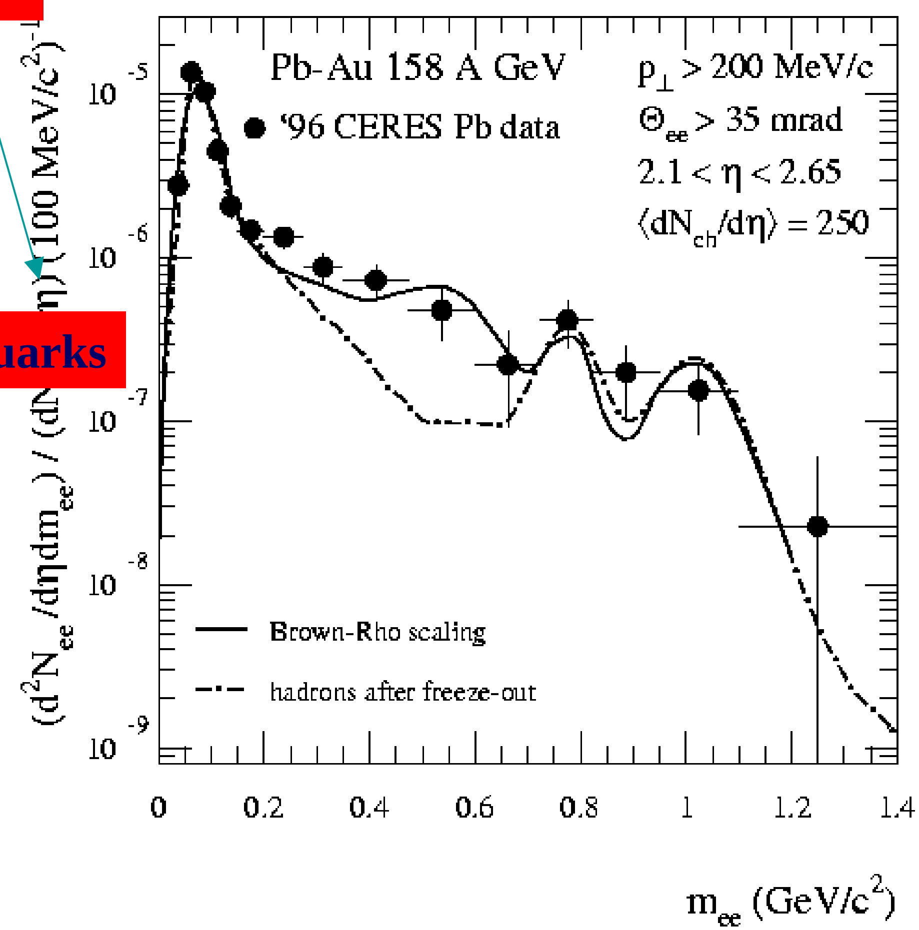
Dropping ρ-meson mass

(G.E. Brown et al)



hadrons

quarks

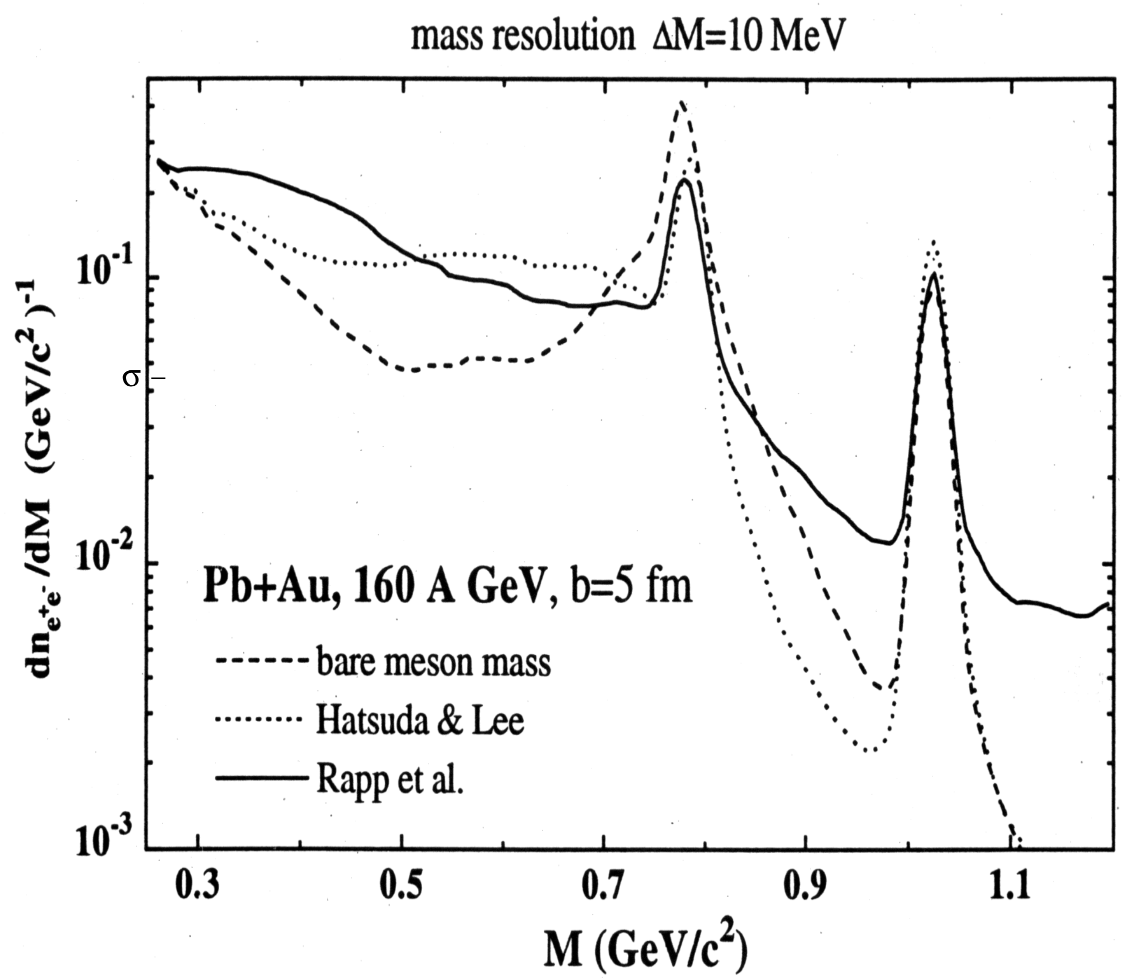


What happens as chiral symmetry is restored? Dropping masses or line broadening?

Quark-hadron duality down to low-masses m ~0.4 – 0.5 MeV/c^2?

Mass Resolution

(Wambach et al.)



Possibility to discriminate between the scenarios of:

ρ-meson dropping-mass and ρ-meson broadening

Excellent mass resolution is needed: $\frac{\sigma_m}{m} = 1\%$ **at the ω peak.**

Low-mass e^+e^- Pairs: Prospects at RHIC

At 160 GeV/u *baryon density* is the dominant factor for dropping masses

$$\frac{m^*}{m} = \left[1 - \left(\frac{T}{T_c}\right)^2\right]^{1/3} \left[1 - 0.2\,\frac{\tilde{n}}{\tilde{n}_B}\right]$$

and also for spectral shape broadening.

- **What can we expect at RHIC?**

	SPS (Pb-Pb)	RHIC (Au-Au)
$dN(\bar{p})/dy$	5	20.1
Produced baryons ($p, \bar{p}, n, \bar{n}$)	20	80.4
$p - \bar{p}$	27	8.6
Participating nucleons ($p - \bar{p}$) A/Z	68	21.4
Total baryon density	88	101.8

Low-mass e^+e^- pairs in PHENIX: *the* problem

- 'Single' e-tracks/evt in the two central arms:

$$N_e = (dN/d\eta)_{\pi^o} * acc * BR * f(p_T \geq 200)$$

350 1/2 x .7 0.012+0.02 0.32 = 1.2 tracks/evt

- **Combinatorial Background:**

B = 1/2 * 1/2 * $N_e^2 e^{-N_e}$ **= 0.1 pairs/evt**

- **Expected Signal (m>200, pt>200): S = 4.2 *** 10^{-4} **pairs/evt**

- **Signal to Background: S/B = 1 / 250**

- **Goal: improve S/B by at least two orders of magnitude**

Must reject single tracks at least to the 90% level

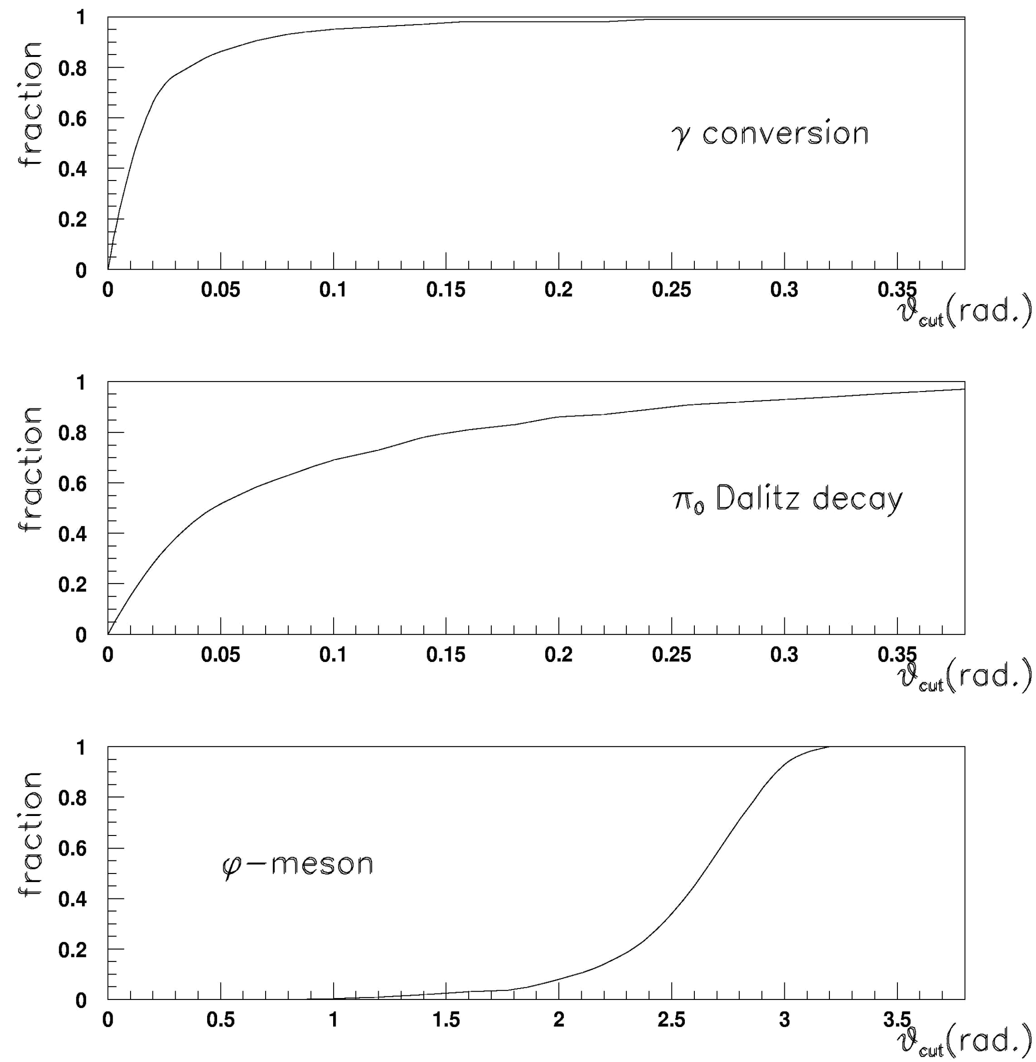
Strategy

- Exploit opening angle distribution

Need:

* field free region near vertex

* detector with e-ID



- For a 90% rejection need opening angle cut up to ~200 mrad

Signal and Background

- ♦ **Inner detector:**
  - *** perfect e-id ε = 100 %**
  - *** perfect dhr = 0 mrad**
  - *** π rejection = ∞**

S / B ~ 10

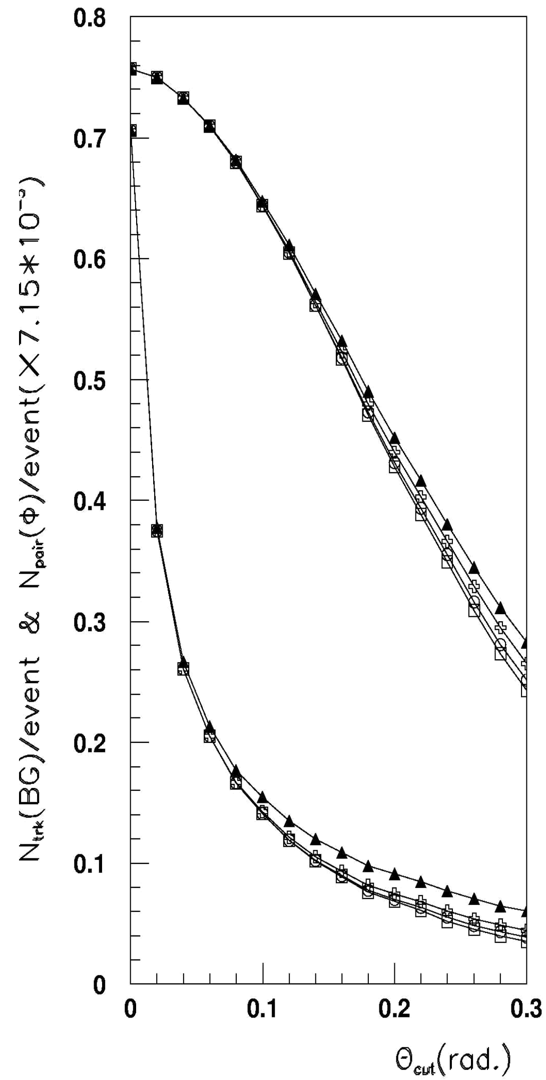
- ♦ **Plus veto area:**

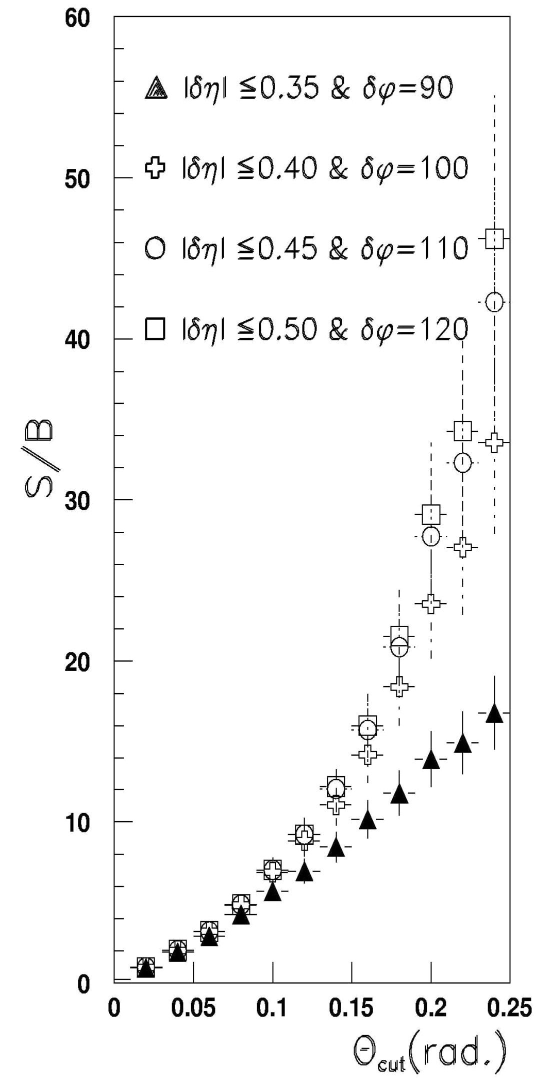
$$|\delta\eta| \leq 0.40 \text{ and } \delta\phi \leq 100^o$$

S / B ~ 30

- ♦ **Under more realistic conditions (including open charm):**

S / B ~ 1 – 3





HBD in PHENIX

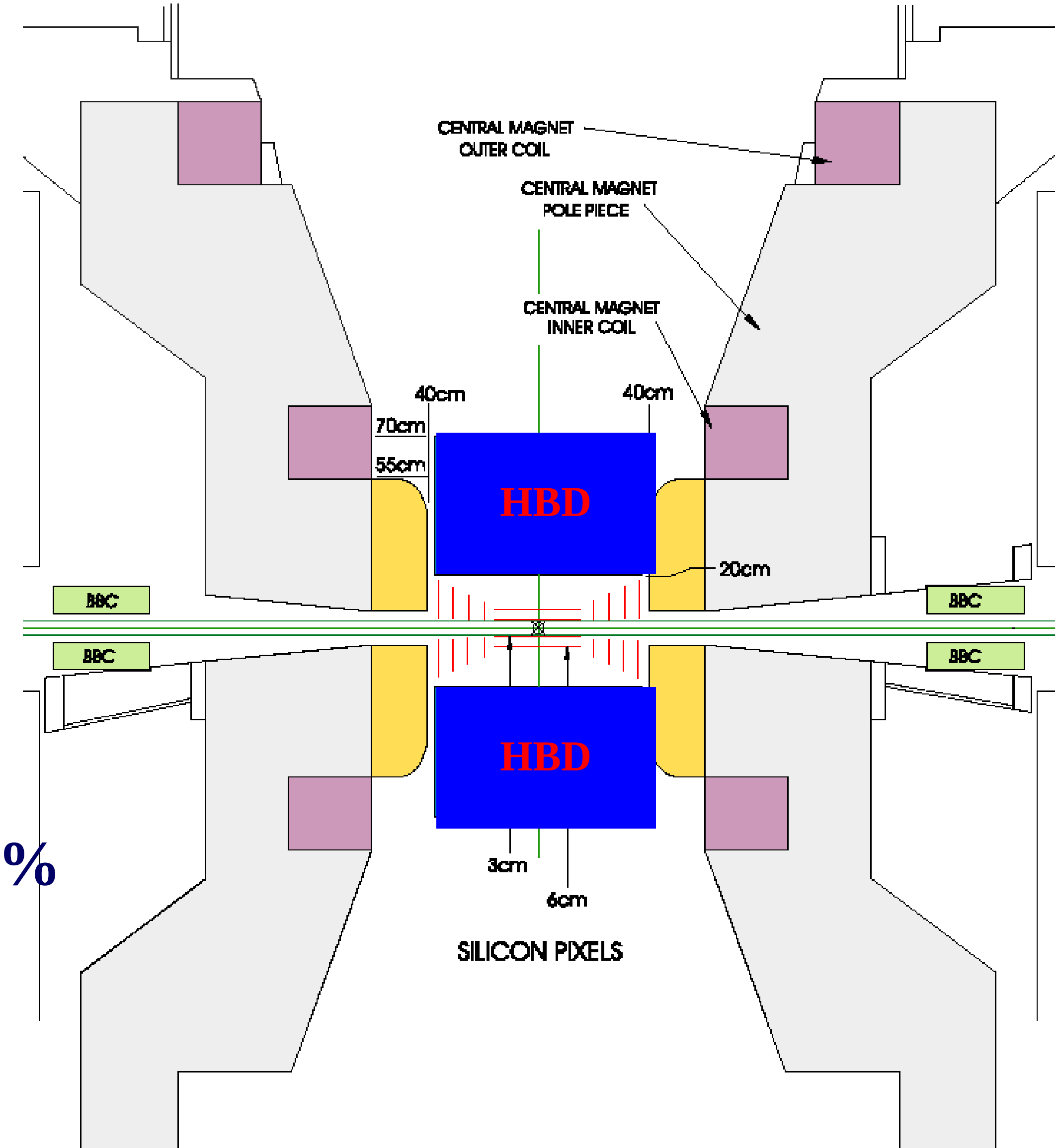
- Compensate magnetic field with inner coil (B=0 for r $\leq$ 50-60cm)

- Compact HBD in the inner region
  Specifications

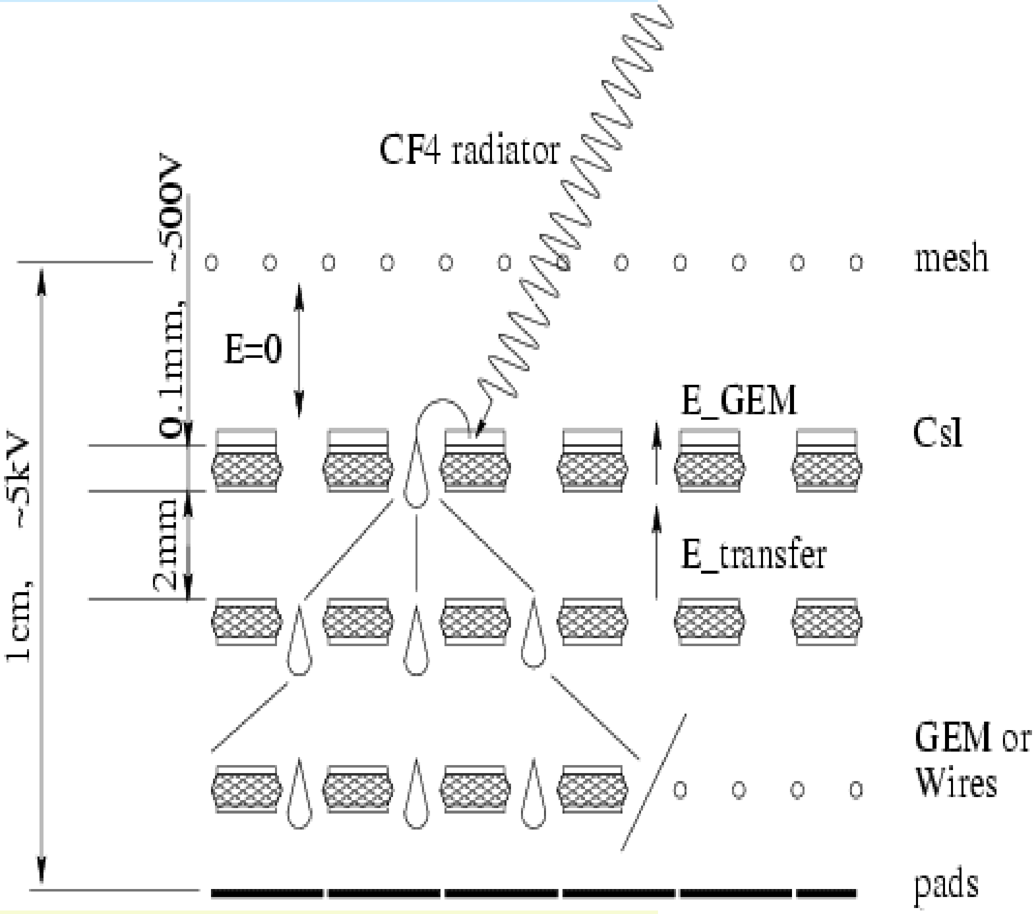
* Electron efficiency $\geq$ 90%

* Modest π rejection ~ 200

* Double hit recognition $\geq$ 90%



Detector Configuration



Concept:

- **Windowless Cherenkov detector**
- **Radiator and detector gas: CF_4**

Large bandwidth and N_{pe} (40!)

•Transmissive CsI photocathode

No photon feedback

•Proximity focus ⇒ blob (R ~1.8cm)

Low granularity

•Detector element: multi - GEM

High gain

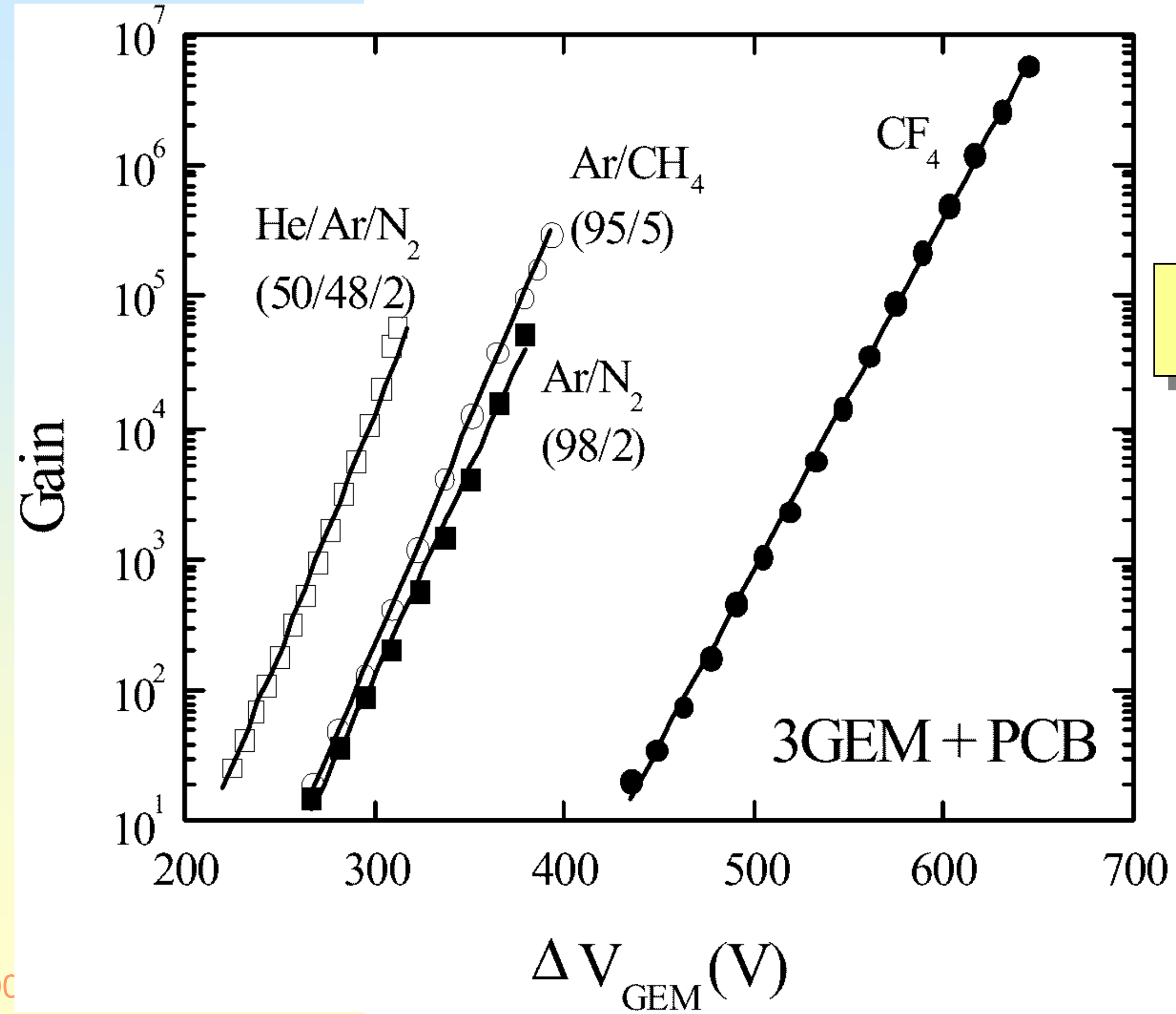
Many open questions but also many backup options

Detector configuration: options

Detector configuration					Response to:						e/π
					electrons				hadrons		
Radiator gas	Photo-cathode	Detector gas	Window	Shades Rad/Det	γ_{th}	N_{pe}	R_{blob} cm	DHR %	N_e G/L	X_o %	rejection
CF_4	Trans.	Same	No	No/No	28	40	1.8	>90	4/1	1.3	$>10^4$
CF_4	Trans.	Same	No	Yes/No	28	35	1.8	>90	1/1	1.3	$>10^4$
CF_4/Ne (1:1)	Trans.	Same	No	No/No	40	30	1.3	~90	2/1	1.1	$>10^4$
CF_4/Ne (9:1)	Trans.	Same	No	No/No	70	20	1.0	~70	1/1	0.9	350
CF_4	Trans.	*CF_4/Ne*	Yes	No/No	28	40	1.8	>90	4/5	1.6	700
CF_4	Trans.	*CF_4/Ne*	Yes	Yes/Yes	28	35	1.8	>90	1/3	1.7	$>10^4$
CF_4	Trans.	*CF_4/He*	Yes	Yes/Yes	28	35	1.8	>90	1/3	1.7	$>10^4$
CH_4	Refl.	Same	No	No/No	34	8	1.5	~40	0/<1	0.6	>6
CH_4	Trans.	Same	No	No/No	34	6	1.5	~30	0/<1	0.8	>2.5
CF_4	SemiT.	Any	Yes	No/No	28	10	1.8	~50	2/10	1.6	Fails
Ne	Trans.	Same	No	No/No	86	20	0.8	~70	?/<1	0.9	?

Detector concept exists! Enough back-up options to solve potential problems

CF$_4$ + GEM + CsI work!



A. Breskin et al, (in press)

A Fast Compact TPC for PHENIX and STAR

• PHENIX Motivation

* Stand-alone tracking detector (2π in azimuth, $|\eta|$~0.7) ⇒ improve jet recognition in pp, improve high p_T measurement in heavy-ion, extend tracking to lower p_T .
* Low-momentum e ID ⇒ rejection of π^o Dalitz and conversions ⇒ low-mass e^+e^- pairs measurement.
* Help to resolve displaced verticies from charm and B decay

• STAR Motivation:

* Replace in 4-5 years the main STAR tracking detector (TPC) to:
  - Study "rare" observables together with other new detectors (RICH, TRD, TOF…?)
  - Cope with expected increase of RHIC luminosity

System specifications

- **Low mass electron pairs**

  Same as for HBD:

  Dalitz rejection > 90%

  Single electron efficiency > 90%

  Pion misidentification probability < 1/200

  (provided by dE/dx in TPC for p < 200 MeV/c)

- **Tracking**

  Coverage over 2π in azimuth, $|\eta| \sim 0.75$

  Provide tracking at low momentum (< 200 MeV/c) with $dp/p \sim 0.02\ p$

  Must have sufficient two track resolution to handle high track densities

  Must operate in high luminosity heavy ion and pp environment

- **Secondary verticies**

  Need to resolve secondary verticies at the level of ~ 50 μm when used in conjunction with silicon vertex detector.

What are the technological choices ?

- **Fast, compact TPC**

  Short drift region, fast drift gas (e.g., CF_4)

  Good spatial resolution (highly segmented readout plane)

  Readout with micropattern detector (GEM, μMega) or MWPC w/pads

  Highly integrated readout electronics

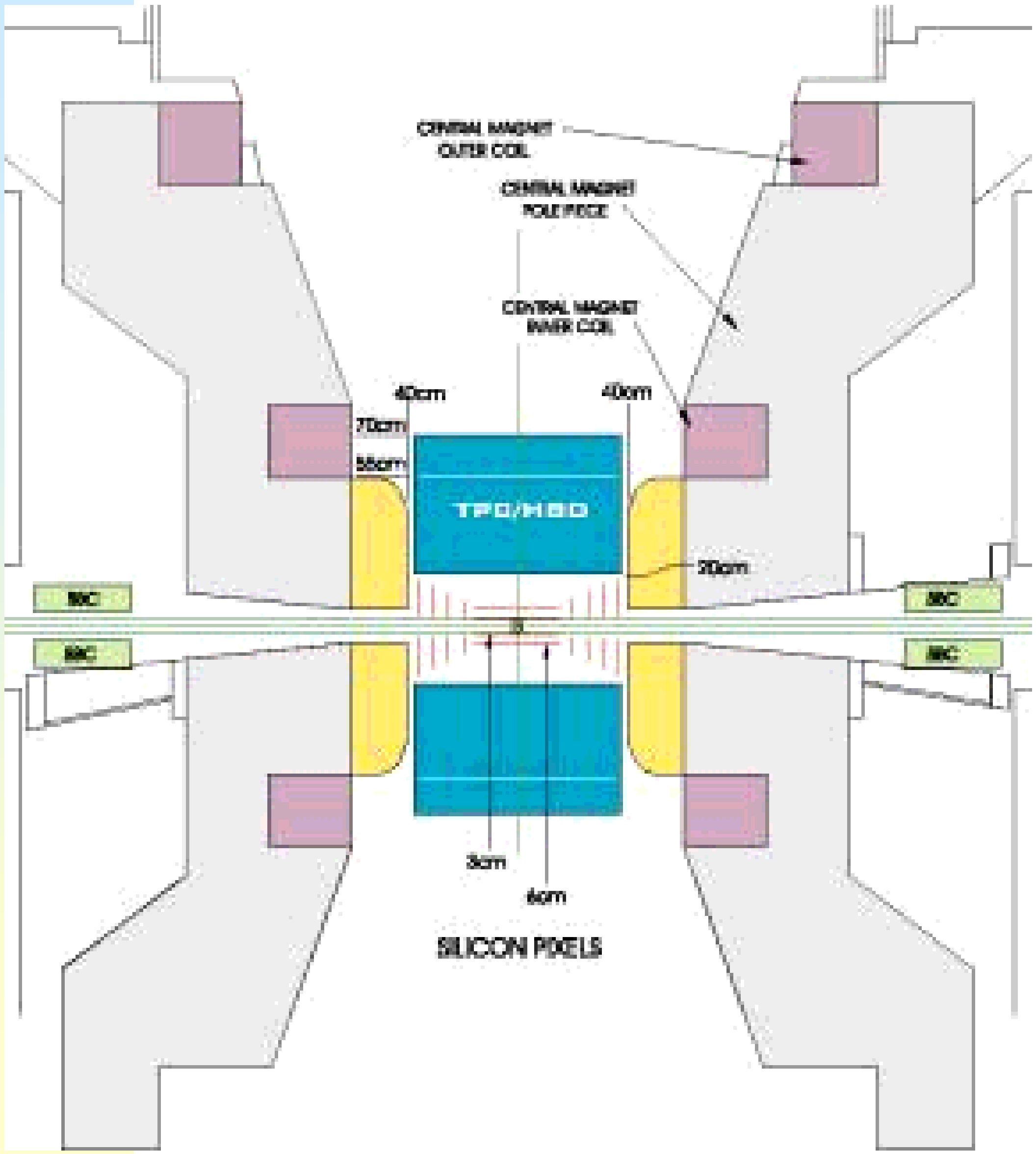
- **Hybrid concept**:

  HBD and TPC together as a single detector (N. Smirnov)

  CF_4 (or CH_4) may serve as:

  * the ionization gas for the TPC
  * the radiator gas for the HBD
  * the operating gas for the readout detector.

A TPC/HBD in PHENIX



R & D programme (I)

- **Generic Detector R&D**

  * Drift velocity, diffusion and dE/dx in CF_4
  * CF_4 scintillation and timing
  * CsI / CF_4 bandwidth
  * CF_4 mixtures with Ne or Ar
  * Gain in GEM for stable operation
  * Aging of CsI and GEM in CF_4
  * Readout detector:
    - options: GEM or μMegas or MWPC ?
    - configuration: 3 GEM or 2GEM + MWPC?
  * Response to electrons and hadrons (N_{pe} per electron and per mip)

R & D programme (II)

• FEE

* Front end electronics specifications
* Readout granularity
* Design of integrated readout electronics

• Simulations

* More realistic Monte Carlo studies of HBD
* Include HBD in MC ➡ optimize response
* Optimize magnetic field configuration
* HBD in presence of some residual magnetic field
* Is the TPC a replacement for the HBD? If not, can the TPC help the HBD by providing additional rejection?